# GRID BASED ROBOT NAVIGATION USINGSMARTPHONE

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## ABSTRACT

*Robots are fast developing to assist humans, replace human labour or provide a safer and luxurious lifestyle to humans. Autonomous robots are a category of robots that can make their own decisions. They can do work without continuous human guidance. Localization involves finding the current location of the robot. Although, this can be done by using GPS, it fails to work efficiently in indoor environments. This paper proposes a model for an autonomous robot that assumes its plane of navigation in the form of a grid and whose navigation can be monitored on a smartphone. The three major phases that are considered here are- Map Building, Path Planning and Localization. Ultrasonic sensors are used to detect and find the position of the obstacles in the grid. The destination location is taken as a user input from the smartphone. This data is used for map building. Path planning is done using A-Star algorithm. The robot moves along the shortest path, avoiding obstacles to the destination. This navigation can be viewed on the smartphone synchronously. The robot is developed using MCB2140 evaluation board which uses LPC2148 microcontroller.*

***Keywords*: *A-Star Algorithm, Autonomous Robot, LPC2148, MCB2140, Smartphone***

## I. INTRODUCTION

'Robotics' is one of the most exciting areas that has been through constant innovation and evolution. Robotics is interdisciplinary and has become more and more a part of our lives. In our day to day lives, robots can be used for many purposes like cleaning the house, mowing the lawn, securing our uninhabited houses or feeding our pets. Within robotics, special attention is given to mobile robots, since they have the capability to navigate in their environment and are not fixed to one physical location.

The mobile robotics field has many challenges that need to be addressed. Navigation (mapping, localization, path planning), environment perception (sensors), autonomous behaviour (actuators, behaviour rules, control mechanisms), two legged movement (balance), capacity to work for an extended period without human intervention (batteries, human assistance), are among the many challenges the robot faces.One of the major challenges the autonomous robot faces is, localization. An easy solution is to use GPS. However, the usability of GPS is constrained in indoor environments. Localization of the robot in an indoor environment without the use of external sensors is a challenge that is addressed in this project.

KokSeng CHQNG, Lindsay KLEEMAN[1] have proposed to use the grid based approach since it gives more concise representation of the environment and is easy to use.Yu-Cheol Lee, Christiand, HeesungChae, and Sung-HoonKim[2] have divided the process of navigation into localization, mapping and path panning which is useful in real time applications. Seung-Hwan Park[3] has used Monte Carlo localization technique to estimate the robot's position in the environment. Dong Jin Seo, Jongwoo Kim[4] have used the A star algorithm for path planning as it is compatible with the grid based environment and gives fast and reliable results.

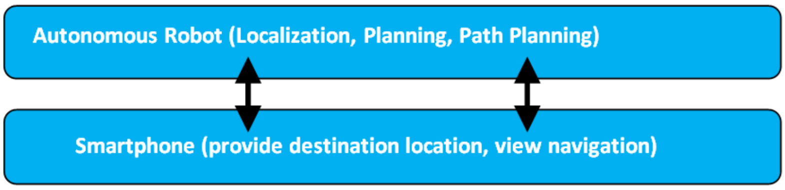



**Fig 1.1 System Architecture Schematics**

The main objectives of the work presented in this paper are- detect the obstacle locations using ultrasonic sensors and using this databuild a map of its environment, develop the shortest path which allows the robot to navigate to the destination avoiding obstacles, and develop a smartphone application that can communicate with the robot.The Fig.1.1 illustrates the structure of the system implemented in the project.

## II. ROBOT NAVIGATION

Robot navigation means the robot's ability to determine its own position in its frame of reference and then to plan a path towards some goal location. In order to navigate in its environment, the robot requires representation, i.e. a map of the environment and the ability to interpret that representation.Navigation can be defined as the combination of the three fundamental competences:

1. Map-building and map interpretation
2. Path planning
3. Self-localisation

### 2.1 Map Building

The main goal of map building is to create a map that provides spatial information for the localization, the path generation, and spatial recognition of obstacles in the environment. This paper uses the grid-based mapping that contains occupied information in each of its cell. It gives more compact representation of the environment.

The robot environment is assumed as a matrix of rows and columns in the form of a grid (Fig. 2.1). Each cell in the grid, corresponding to a particular row and column, is a unique location in the grid. The data obtained from the sensors is manipulated to obtain the obstacle location in the grid. The final map (Fig 2.2) consists of the locations of the boundaries and the obstacles in the grid.

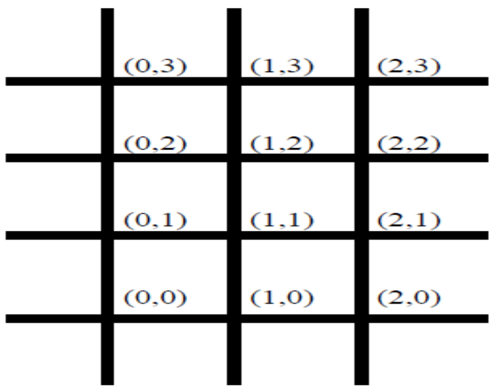



**Fig. 2.1 Grid based mapping**

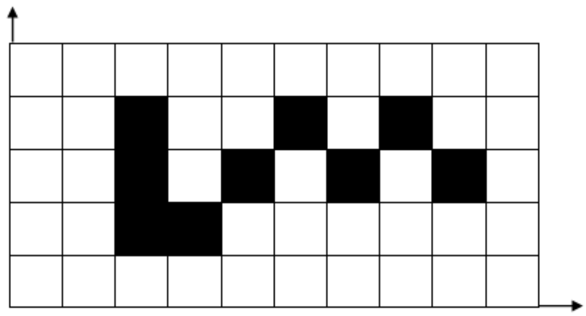


**Fig. 2.2 Final Map**

## 2.2 Localization

The localization refers to the problem of estimating the robot position. The localization module in this paper uses the Monte Carlo localization algorithm based on random numbers to update the robot pose information. This technique involves estimating the state of the robot at the current time step, given the knowledge about previous state of the robot. It uses details of the robot such as position along the x- axis (column number- x) and y-axis (row number- y) and the orientation (ϴ). The state vector[x, y, ϴ] is updated at every cell crossing in the grid. Depending on the orientation at the current time, the row and column positions are incremented or decremented. If the robot turns, the orientation is also updated depending on which direction it turns. The robot is assumed to turn about 90˚. Thus it can be in any of the four orientations- North, South, East or West. The updated values of x, y and ϴ gives the current position and orientation of the robot.

## 2.3 Path Planning

Path Planning is the process of looking ahead at the outcomes of the possible actions, and searching for the sequence of actions that will drive the robot to the desired goal. It involves finding a path from the robot's current location to the destination. The cost of planning is a very important issue for real-time navigation needs, and the longer it takes to plan, the longer it takes to find a solution.

The A-star path planning algorithm is used in this project for two reasons. Firstly, this algorithm is highly compatible with the grid based representation of the environment. Secondly, this algorithm is efficient and gives the shortest possible path from source to destination.A* uses a best-first search and finds a least-cost path from a given initial node to one goal node. As A* traverses the graph, it follows a path of the lowest expected total cost or distance, keeping a sorted priority queue of alternate path segments along the way. It uses a total cost function F which is a sum of two functions:

- A heuristic cost function (H) that denotes the distance from a node to the target node.
- A movement cost function (G) that denotes the cost for moving from the current node to the adjacent nodes.

F becomes the estimated cost of the shortest solution through node.Two set of lists are maintained

- An open list that contains the list of nodes to be checked
- A closed list that contains a list of nodes that have been checked

It follows the algorithm steps are as follows:

1. Initially, calculate the H cost for each node in the grid. Assume a constant value as the G cost and path_cost as 0.
2. Create a list called ClosedList that is initially empty.
3. Select the first node and put it in ClosedList. Call this node n.
4. Determine the adjacent nodes of node n.

5. Calculate the total cost (F=H+G+path_cost) for each node.
6. Select the node with the smallest F cost as the next node (n) in the ClosedList.
7. If n is a goal node, exit successfully with the solution obtained by tracing a path along the nodes from n to n0.
8. Otherwise, repeat from step 4.

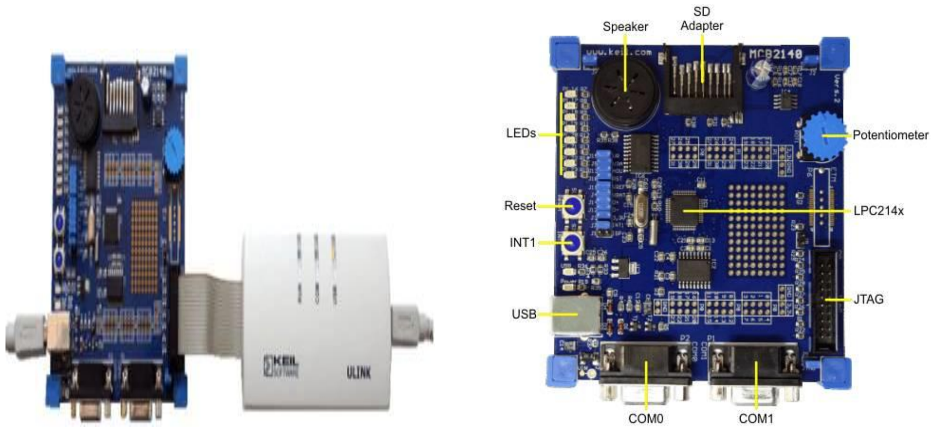
The final path is obtained as shown in the Fig. 2.3.

**Fig. 2.3 A-Star Algorithm**

## III. HARDWARE COMPONENTS

### 3.1 Mcb2140

The Keil MCB2140 Evaluation Board uses the NXP (founded by Philips) LPC2148 microcontroller. The Keil MCB2140 Evaluation Board connects to the PC using the serial port (for Flash download using FlashMagic) or the JTAG interface (for program debug using a Keil ULINK family USB-JTAG Adapter (Fig. 3.1(a)) and the µVision IDE and Debugger). An on-chip USB interface, two serial interfaces, a speaker, analog input (via potentiometer), and eight LEDs are available on this board (Fig. 3.1(b)).




**(a)** **(b)**

**Fig 3.1(a) MCB2140 board connected to ULINK debugger and (b) the components on the board.**

### 3.2 Ultrasonic Sensor

The ultrasonic sensor HC-SR04 (Fig. 3.3) is used to detect obstacle locations and boundaries in the grid. The HC-SR04 includes an ultrasonic transmitter, receiver and control circuitry. It has a range of about 2cm to 400cm, with a measuring angle of 15˚. It works on 5V supply and working frequency of 40Hz. The module consists of three pins- Echo, Trigger, Ground and Vcc.

**Vcc Trigger Echo Ground**

Fig 3.3 SR-04 ultrasonic sensors

### 3.3 DC Motor and Motor Driver

Two DC Gear motors are used to rotate the wheels. The motors operate at 12V and 150 RPM. It has a 6mm shaft with an internal hole. These motors are used as they help in increasing the torque and reducing the speed.The L298D motor driver (Fig. 3.4) is used to control the direction of motor rotation. It is a high voltage, high current dual full-bridge driver that accepts standard TTL logic levels. Two enable inputs are provided to enable or disable the device independently of the input signals.

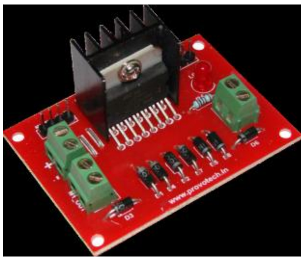


**Fig 3.5 L298D Motor Driver**

The operation of the motors is given in the TABLE below:

**Motor Operation**

| Motor1 Input | | Motor2 Input | | Enable1 | Enable2 | Motor1 Status | Motor2 Status |
|---|---|---|---|---|---|---|---|
| X | | X | | Low | Low | Stop | Stop |
| High | Low | High | Low | High | High | Forward | Forward |
| Low | High | Low | High | High | High | Backward | Backward |
| High | High | High | High | High | High | Stop | Stop |
| Low | Low | Low | Low | High | High | Stop | Stop |

### 3.4 Bluetooth Module

The Bluetooth module- HC05 Bluetooth Tranciever (Fig. 3.6) is used for communication between the microcontroller and the smartphone. It works as a serial (Rx/Tx) pipe. It can be powered using 3.3V to 6V power supply. It uses bluetooth protocol specification v2.0+EDR at frequency of 2.4Ghz ISM band with GFSK(Gaussian Frequency Shift Keying) modulation.

**Fig 3.6 HC-05 BluetoothTtranciever**

## IV. ANDROID

The android application is developed using Eclipse software with Android SDK installed in it. The grid layout is developed using the GridView layout that displays a two-dimensional (rows and columns) scrolling grid.The cells are updated using the ListAdapter.

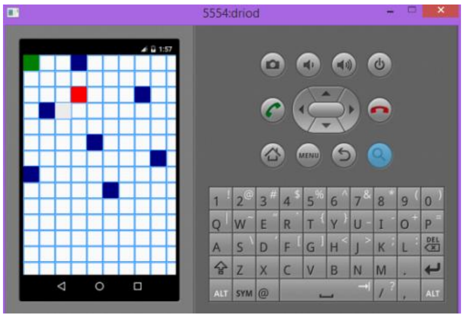



**Fig 3.7 Emulation in Android**

## V. PROPOSED SYSTEM

The robot is built using the MCB2140 evaluation board. Keil µVision4 software is used to program the microcontroller in C language. The port0 GPIO pins are used to connect to the motor driver and ultrasonic sensor and Bluetooth modules. The map building, path planning and localization are done by the microcontroller. The smartphone is used for display purpose and to get the user input. The flowchart for the proposed system is as below:

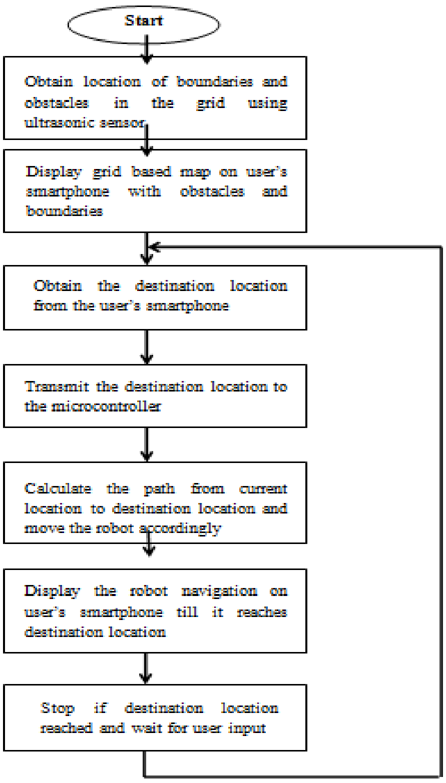



**Fig 4.1 Flowchart of Proposed Model**

## VI. RESULTS

The robot was built using MCB2140 board and ultrasonic sensors, DC geared motors, motor driver, Bluetooth module and wheels (Fig. 6.1). The program was loaded into the microcontroller. The smartphone was used to communicate with the robot and view its navigation.

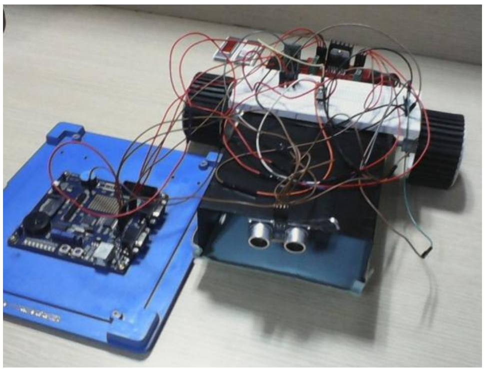


**Fig. 6.1 Snapshot of Grid Based Robot**

## VII. CONCLUSION

This paper introduced the usage of an autonomous robot in various environments and applications. The robot used grid type surface for navigation and localization. Various algorithms were introduced for the map building, localization and path planning of the robot. The hardware and software components were discussed in detail. Thus, the robot can efficiently plan the shortest path to its destination while avoiding obstacles.The robot is developed to operate in small indoor environments only. These robots can be used in controlled automation, industrial and home automation.

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